THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

EFFECT OF TEST RATE AND CONDITIONING TIME ON EDGEWISE COMPRESSION

Project 1108-4

A Preliminary Report

to

TECHNICAL DIVISION
FOURDRINIER KRAFT BOARD INSTITUTE, INC.

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SUMMARY

1. The mechanical properties of fiberboard are sensitive to rate of application of stress or strain, requiring consideration of test rates for formulating test procedures. A brief study indicated that the edgewise compression strength of combined board increases by 1/2 to 1%, on the average, with an increase of 0.01 in./min. in test rate (in the range of .0125 to .0625 in./min.). This information should be helpful in formulating test methods and comparing test results between testing machines and/or between laboratories where different test rates are employed.

2. It may be anticipated that reinforcing the loading edges of compression specimens of combined board and components with molten wax drives off moisture and thereby increases the apparent compression strength if the specimens are tested immediately rather than being permitted to recondition to their equilibrium moisture content. A limited study indicated that the strength may be increased from 0.5 to about 3.5% relative to a 16-hour reconditioning period. For control of quality, the effect under study is probably inconsequential and testing after one-half hour should be satisfactory. Referee or research evaluations would benefit from 16-hour reconditioning.

The results of this study are shown in Table I and in Fig. 1. The data reveal a definite trend of an increase in edgewise compression strength with increase in test rate, as may be anticipated for viscoelastic materials. In terms of the data of Table I, the higher test rates gave increases in edgewise compression of from 1 to 3.6%, relative to the test rate used at The Institute of Paper Chemistry.

TABLE I

EFFECT OF TEST RATE ON EDGEWISE COMPRESSION
STRENGTH OF COMBINED BOARD
(Cross-direction)

	Edgewise Compression Strength			
	Sample A-175		Sample B-275	
Test Rate, in./min.	lb./in.	Diff., %[a]	B-275	Diff., %[a]
0.0125	45.5	-3.6	70.8	-3.3
0.03125	47.2	--	73.2	--
0.050	47.7	+1.1	73.9	+1.0
0.0625	48.0	+1.7	75.8	+3.6
0.075	48.1	+1.9	75.1	+2.6

[a]Arbitrarily based on 0.03125 test rate used at The Institute of Paper Chemistry.

The effect of test rate may be viewed in the graph of Fig. 1. Straight lines were fit to the data by the method of least squares for the purpose of smoothing out experimental variations and revealing thereby the average trend due to test rate. In the case of Sample A-175, the strength at the lowest test rate suggests a curvilinear relationship and was omitted from the curve fit.

The slope of each line is the sensitivity of edgewise compression to test rate. It is convenient to consider the sensitivity in terms of increments

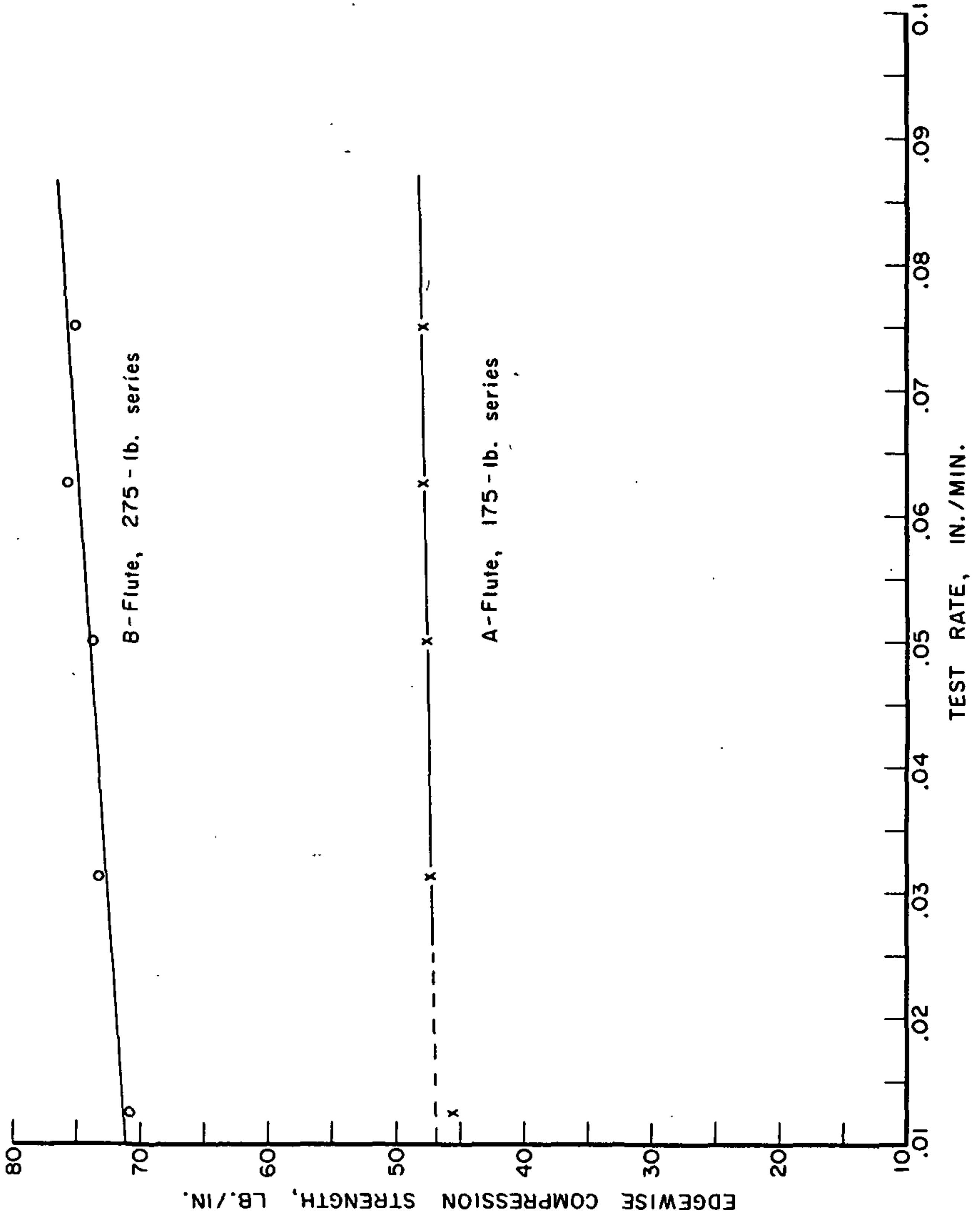

Figure 1. Effect of Test Rate on Edgewise Compression Strength of Combined Board (Cross-Direction)

of 0.01 in./min. of test rate, inasmuch as this size increment may enter practical discussions of test rate. In the case of Sample A-175, the sensitivity was 0.21 lb./in. per 0.01 in./min. increment of test rate (meaning that an increase of 0.01 in./min. in test rate can be expected to increase the edgewise compression by 0.21 lb./in., on the average, in this range of rates). This increase is approximately 1/2 of 1% of the test level.

In the case of Sample B-275, the sensitivity to test rate was 0.73 lb./in. per 0.01 in./min. increment of test rate. This sensitivity is approximately 1% of the test level.

Considering both samples, it may be concluded that an increase of 0.01 in./min. in test rate can be expected to increase edgewise compression strength by 0.5 to 1.0%. This information should be helpful in estimating the effect of test rate differences between laboratories or between standard methods. As an example, an increase in test rate from 0.050 to 0.075 in./min. may be expected to increase edgewise compression by 1.25 to 2.5%, based on the results of this study. This is a systematic difference, apart from the variability due to sampling and testing which also contributes to the uncertainty of an edgewise compression determination.

EFFECT OF CONDITIONING TIME AFTER EDGE REINFORCEMENT

Over the past several years improved test procedures have been developed for evaluating the edgewise compression strength of combined board and components. These innovations were based on the concept of reinforcement of the loading edges of the specimen to prevent failure of the edges. Reinforcement is accomplished by dipping the specimens in a 1/4-inch deep bath of molten wax in the case of combined board and touching the edges against a pad saturated with molten wax in the case of components. In either case the wax temperature is approximately 175°F.

It is anticipated that exposure of the specimen to this elevated temperature may drive off some of its moisture. Accordingly, if the specimen were tested immediately it would be expected that the strength may be higher than that corresponding to equilibrium moisture content in the standard test atmosphere. It has been the practice to allow the specimen to condition overnight (at least 16 hours) in the test atmosphere during which time the specimen can return to equilibrium moisture content on the absorption cycle.

This reconditioning period is no great inconvenience when the edgewise compression test is being performed as a research or referee test; preparation and testing of samples can be scheduled to accommodate the reconditioning period. It is clear, however, that the reconditioning period is inconvenient, and in fact prohibitive, from the standpoint of control of quality in the mill and box plant.

A study was undertaken to determine the degree to which edgewise compression strength depends upon reconditioning time after reinforcement of the loading edges of the specimen. The reconditioning times investigated were 0, 1/2, 1, 2, 6, and 16 hours. These nominal reconditioning periods refer to the elapsed time from conclusion of the edge reinforcement on the last of 20 specimens of a given sample of board until the beginning of testing on the first specimen of the sample.

[There is, of course, a range of actual reconditioning times for individual specimens of the sample because preparation and testing times differ. In the case of "zero" conditioning time, the actual times ranged from about three minutes for the first specimen of a combined board sample to 20 minutes for the last specimen. This gives a median time of about 12 minutes or 0.2 hour, rather than zero, for the sample. This disparity occurs for each nominal reconditioning period but becomes diminishingly important as the period increases.]

A sample of 42-lb. kraft liner and of 69-lb. kraft liner were evaluated in cross-direction modified ring compression in an H & D compression tester after each degree of reconditioning. Similarly, a sample of A-flute, 175-lb. series combined board and of B-flute, 275-lb. series board were evaluated in cross-direction edgewise compression (short column) with a Baldwin universal testing machine. Specimen dimensions were 6 by 1/2 inches for modified ring compression and 1.25 inches high by 2.0 inches wide for combined board edgewise compression. In both types of specimens the loading edges were reinforced with Mobilwax D paraffin at 175°F. in the usual manner. All aspects of the test procedure, other than reconditioning time, were as described in References (2) and (3).

Precautions were taken to maintain all test conditions constant, other than reconditioning time. All specimens from a given sample of board were cut during one session and randomized into groups of 20 specimens — one group per reconditioning period. All testing of a given sample of board was accomplished on one testing machine by one operator within an 8-hour period, without disturbing the testing machine setup between samples. The order of testing the reconditioned samples was: 16 hours reconditioning, zero, one, 2, 1/2, and 6 hours reconditioning. This schedule was convenient from the standpoint of scheduling and, more importantly, should average out any time trends which possibly may be associated with the test equipment or operator.

The test results are shown in Table II and Fig. 2 and 3. The modified ring compression of the sample of 42-lb. liner ranged from 19.3 lb./in. at zero time to 18.7 lb./in. at 16 hours, a difference of 3.2%. In this case there was a more or less progressive decrease in strength with increase in conditioning time.

With the sample of 69-lb. liner, on the other hand, there appears to be an increase in strength with increase in conditioning time. This trend is not anticipated. The slope of a straight line fit to the data by the method of least squares does not differ significantly from zero and thus it seems likely that the apparent trend is a chance occurrence attributable to the inherent variability associated with sampling and testing.

In the case of the A-flute combined board the test values exhibited substantial scatter. The greatest difference occurred between 6 and 16 hours and the load for the latter was 5.8% lower than for the zero period. The zero and 16-hour periods had been studied on an earlier occasion with the same sample, giving 46.95 and 46.38 lb./in., respectively — a difference of only 1.2%. Thus, it is questionable whether the aforementioned large difference is representative.

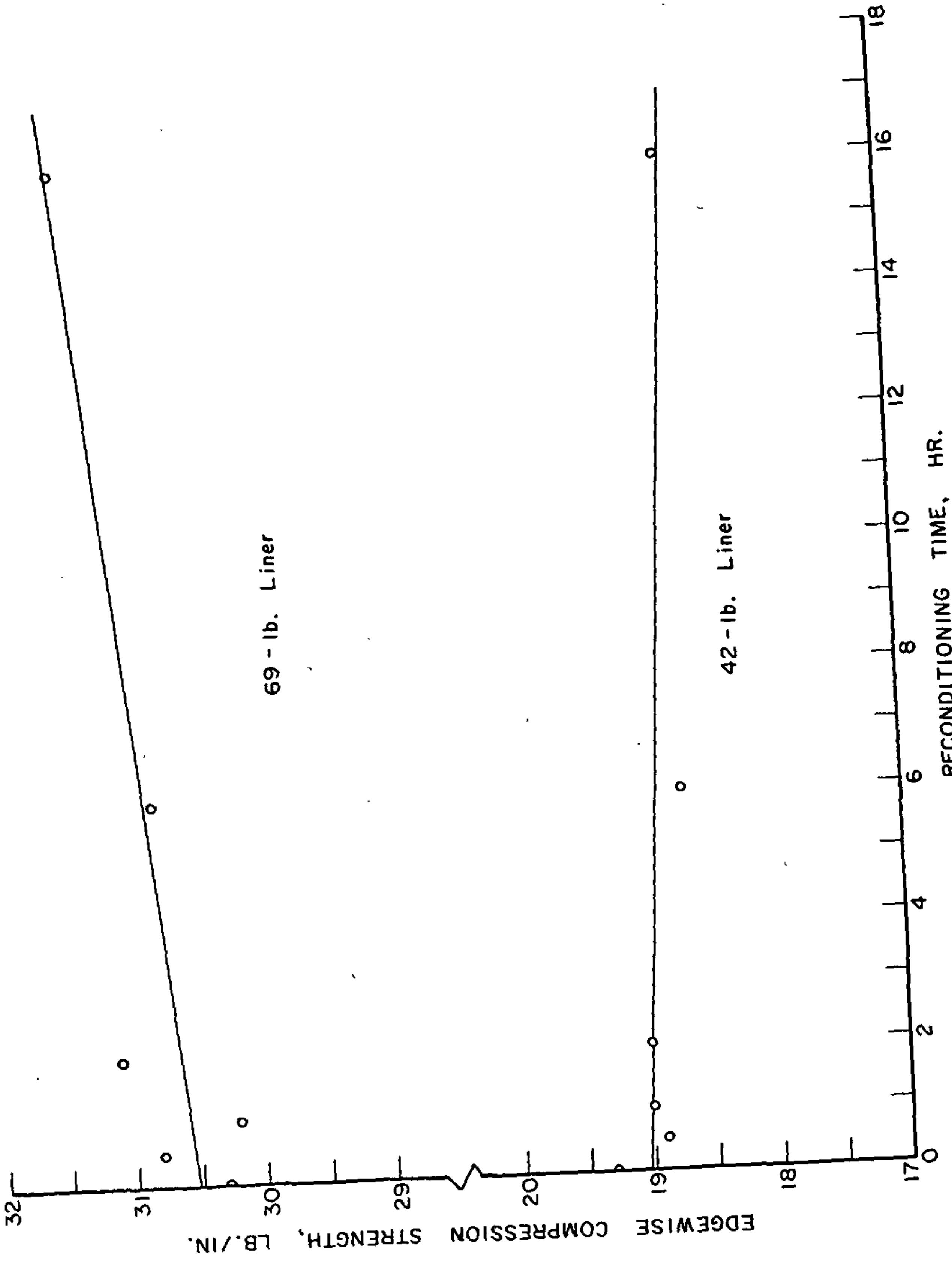

Figure 2. Effect of Reconditioning Time on Component Edgewise Compression (Cross-Direction)

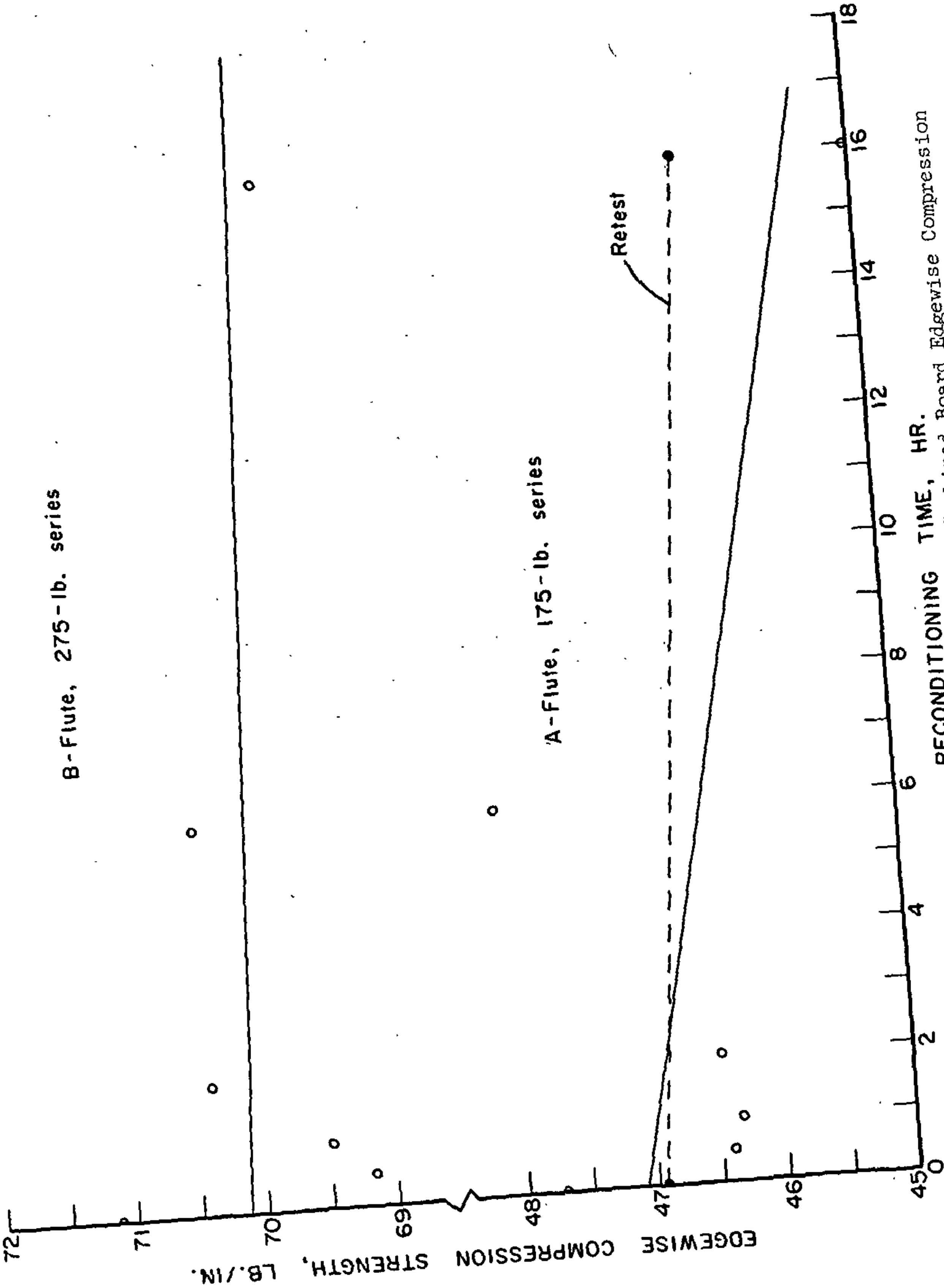

Figure 3. Effect of Reconditioning Time on Combined Board Edgewise Compression
(Cross-Direction)

TABLE II

EFFECT OF RECONDITIONING TIME ON
EDGEWISE COMPRESSION STRENGTH

Reconditioning Period, hr.	42-lb. liner lb./in.	42-lb. liner Diff., %[a]	69-lb. liner lb./in.	69-lb. liner Diff., %[a]	A-175 lb./in.	A-175 Diff., %[a]	B-275 lb./in.	B-275 Diff., %[a]
	Edgewise Compression Strength							
0	19.3	+2.0	30.3	-1.5	47.72[b]	+2.2	71.12	+1.6
1/2	18.9	-0.2	30.8	+0.1	46.42	-0.6	69.16	-1.2
1	19.0	+0.4	30.2	-1.9	46.34	-0.7	69.49	-0.8
2	19.0	+0.4	31.1	+1.1	46.48	-0.4	70.39	+0.5
6	18.7	-1.2	30.8	+0.1	48.09	+3.0	70.40	+0.5
16	18.7	-1.2	31.4	+2.0	45.02[c]	-3.6	69.59	-0.6
Av.	18.93		30.77		46.68		70.02	

[a]Based on average of all conditions.

[b]Retest: 46.95 lb./in.

[c]Retest: 46.38 lb./in.

With the B-flute board there is evidence of a slight decreasing trend, with the extreme conditioning intervals differing by 2.2% in edgewise compression.

The objective of this experiment was to obtain an estimate of the variation of edgewise compression with reconditioning time. For this purpose it should be helpful to fit a curve to the strength vs. time data which smooths out the scatter and indicates the average trend. Straight lines were fit to the data as shown in Fig. 2 and 3. It is recognized that the relationship is probably not truly linear; however, there are not enough data in this study to find a suitable curvilinear fit. Straight lines should be adequate for smoothing purposes over the range of times of interest.

The slope of each line is the average sensitivity of edgewise compression to reconditioning time and has units of lb./in. per hour of reconditioning time. The slopes for these samples are as follows:

Sample	Sensitivity, lb./in. per hour
42-lb. liner	-0.026
69-lb. liner	+0.055
A-flute, 175-lb.	-0.100 (-0.036)[a]
B-flute, 275-lb.	-0.027

[a]Based on a second evaluation of 0 and 16 hours.

Viewed in another way, the strengths at each reconditioning period may be read from the fitted lines to give an estimate of the average effect of reconditioning time apart from experimental scatter. These "smoothed" results are shown in Table III. It may be seen that the differences in edgewise compression between zero and 16 hours reconditioning are +2.1, -2.8, +3.5, and +0.5% for the 42-lb.

TABLE III

EFFECT OF RECONDITIONING TIME ON EDGEWISE COMPRESSION
(Smoothed data)

Reconditioning Period, hr.	Edgewise Compression Strength							
	42-lb. liner		69-lb. liner		A-175		B-275	
	lb./in.	Diff., %[a]	lb./in.	Diff., %[a]	lb./in.	Diff., %[a]	lb./in.	Diff., %[a]
0	19.04	+2.1	30.53	-2.8	47.10	+3.5	70.14	+0.5
1/2	19.03	+2.0	30.56	-2.7	47.05	+3.4	70.12	+0.5
1	19.01	+1.9	30.59	-2.6	47.00	+3.3	70.11	+0.5
2	18.99	+1.8	30.65	-2.4	46.90	+3.1	70.09	+0.5
6	18.90	+1.3	30.86	-1.8	46.49	+2.2	70.00	+0.3
16	18.65	--	31.41	--	45.50	--	69.77	--

[a]Based on value at 16 hours conditioning.

liner, 69-lb. liner, A-flute, and B-flute combined board, respectively. As noted above, the trend with the 69-lb. liner (-2.8%) is in an unexpected direction from physical considerations and may not be real. Also the +3.5% difference for the A-flute sample may be on the high side.

In some applications such as quality control testing modest variations in reconditioning time may be inconsequential compared with the uncertainty in the test value due to sampling and testing variability. Experience has revealed that this latter variability is typically about 5% (i.e., the standard deviation expressed as a per cent of the test level). Accordingly, the uncertainty in an average from five specimens is $\pm 6.2\%$ (these are 95% confidence limits); with 10 specimens the uncertainty is $\pm 3.6\%$. In these instances it may be relatively unimportant to be concerned with small variations in reconditioning time.

It should be emphasized that the straight lines used above for smoothing the data are probably not strictly appropriate. General experience with moisture absorption effects is that the greatest change in moisture content takes place in the first few increments of time, although considerably more time may be required to reach absolute equilibrium. With this in mind it may be noted in Fig. 2 and 3 that the test levels at 1/2 and 1 hour of conditioning are generally substantially closer to the 16-hour test level than is the zero test level. Statistical analysis revealed that in all cases the strength at zero time was significantly higher (0.05 level) than the composite strength of 1/2 through 16 hours (except for the 69-lb. liner which exhibited an increase in strength with increase in conditioning time). It should be noted that this statistical analysis is based on the assumption that the moisture content is nearly stabilized after 1/2 hour. This behavior is probably closer to reality than the linear relationship corresponding to the straight lines in Fig. 2 and 3. These results indicate that it may be prudent to wait at least one-half hour after preparation of reinforced compression specimens before testing.

For referee testing or research tests where differences of several per cent may assume greater importance it is recommended that the compression specimens be reconditioned for 16 hours after reinforcing the edges.

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